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Element concentrations in globemallow herbage

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Abstract

Globemallows (*Sphaeralcea* spp.) are native, drought-resistant forbs of interest for inclusion in seed mixtures for semiarid rangeland renovation. Little is known of their nutritional value for ungulates. We measured element concentrations in representative globemallow species and evaluated their adequacy for livestock nutrition. We also correlated forage selection by sheep *(Ovis aries)* with element concentrations. Alfalfa (*Medicago sativa* L.), crested wheatgrass [*Agropyron cristatum* (L.) Gaertn. × *A. desertorum* (Fisch.) Schult.], and 13 accessions of globemallows [*S. coccinea* (Pursh) Rydb., *S. grossulariifolia* (H. & A.) Rydb., *S. munroana* (Dougl) Spach., and *S. parvifolia* A. Nels.] were transplanted into replicated grazing trials in southern Idaho. Herbage was sampled and the pastures were grazed by sheep in the fall of 2 years and in the spring of the following 2 years. Concentrations of Ca and Mg in crested wheatgrass were lower than in forbs. Differences between seasons were greater than the differences among globemallow species. Forage selection ratios were positively associated with the N concentration of globemallow leaves and with the Ca:P ratio of globemallow stems but were negatively associated with stem Zn concentrations. Herbage from pastures containing crested wheatgrass with globemallows and/or alfalfa would meet the dietary element requirements of beef cattle *(Bos taurus)* and sheep.

Key Words: *Agropyron,* grazing behavior, *Medicago,* nutrient concentrations, pasture, rangelands, sheep

Element concentrations in forbs often remain relatively high as forbs senesce (Cook 1983). Consequently, forbs can extend the grazing season and increase total livestock production on grazed lands. Cook (1983) stated, "Thus, for no other reason than to meet protein and phosphorus requirements of grazing animals, grassland ranges should be managed for a mixture of forbs and grasses in the stand." Many forbs are digested more rapidly than grasses (Holechek et al. 1989) and leguminous forbs in a sward minimize the incidence of grass tetany (Robinson et al. 1989).

Globemallows (*Sphaeralcea* spp.) are drought-tolerant native perennial forbs that grow well with bunchgrasses in mixed species stands varying from salt desert sites to dry foothills in sagebrush (*Artemisia* spp.) and pinyon-juniper [*Pinus edulis* Engelm./*P. monophylla* Torr. & Frem.-*Juniperus osteosperma* (Torr.) Little] dominated ranges (Plummer et al. 1968, Sharp et al. 1990). Adapted globemallow species may be appropriate components of seed mixtures for rangeland seedings (Pendery and Rumbaugh 1986, 1990). Sheep *(Ovis aries)* preferred spring growth of globemallows to that of crested wheatgrass [*Agropyron cristatum* (L.) Gaertn. × *A. desertorum* (Fisch.) Schult.] (Rumbaugh et al. 1993). Forbs, including 2 species of globemallow, generally were preferred over grasses by pronghorn (*Antilocapra americana* Ord), sheep and cattle *(Bos taurus)* in New Mexico studies (Howard et al. 1990). *Sphaeralcea angustifolia* [(Cav.) Don] was the most important forb in the diet of goats *(Capra hircus)* grazing desert grassland in northern Mexico (Mellado et al. 1991). Forbs, including *S. coccinea,* were comparable to alfalfa hay for improving low-quality forage diets of beef steers (Arthun et al. 1992).

Development of appropriate element supplementation strategies for livestock depends upon knowledge of the elements provided by plant species at various stages of phenology. Our objectives were to measure the element concentrations in fall and spring growth of 4 globemallow species, to relate those concentrations to published values of livestock nutritional requirements, and to

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determine whether these element concentrations influenced dietary selection by sheep. Crested wheatgrass and alfalfa were used as standards.

Materials and Methods

Establishment of Pastures

Three-month-old plants of 13 globemallow accessions representing 4 species indigenous to the Intermountain Region [*S. coccinea* (Pursh) Rydb., *S. grossulariifolia* (H. & A.) Rydb., *S. munroana* (Dougl) Spach., and *S. parvifolia* A. Nels.] plus 'Hycrest' crested wheatgrass *(A. cristatum* × *A. desertorum)* (Asay et al. 1985) and 'Spredor 2' alfalfa *(Medicago sativa)* were transplanted from a greenhouse to the field on 18–20 Apr. 1988. The study site was on a Portneuf silt loam (coarse, silty, Durixerollic Calciorthid) soil near Kimberly, Ida. Rooting depth on this site varies from 300 to more than 1,000 mm and average annual precipitation is 230 mm. The measured 12-month precipitation preceding each grazing period was 204, 247, 230, and 190 mm for 1988, 1989, 1990, and 1991, respectively. Plants that did not survive transplanting were replaced in May 1988. Plants that died during the subsequent winter were replaced on 4 and 5 Apr. 1989.

Experimental Design

The experiment had 4 pastures, each of which contained 6 replications of the 15 plant accessions in a randomized complete block design. Each plot consisted of 4 plants of an accession separated by single plants of crested wheatgrass. Each plot was separated from adjacent plots by 2 rows of crested wheatgrass plants. All plants were spaced 1.0 m apart within and between rows. Pasture 4 was used as a sheep conditioning area to accustom the animals to the experimental environment, and forage was not sampled in that pasture. Replication 6 in pastures 1, 2, and 3 was used to measure pre- and post-grazing herbage biomass. Only replications 1 to 5 in each pasture were grazed. Details of the agronomic and livestock management of the pastures are provided by Rumbaugh et al. (1993).

Sampling and Chemical Analyses

Herbage was sampled in the fall (October) of 1988 and 1989 and in the spring (May) of 1990 and 1991. Stems were manually separated from the leaves and finer petioles (<1 mm) of plants harvested in replication 6 of each pasture. All samples were placed in a forced draft oven (60° C) until dry and ground in a Wiley mill to pass through a 1-mm screen. Herbage subsamples were digested in $HNO_3/HClO_4$, diluted with H_2O, and analyzed for Na, Cu, Fe, Mn, and Zn by atomic absorption (AA) spectroscopy (Greweling 1976). An aliquot of the initial digest was diluted to contain 1 mg liter^{-1} and Ca and Mg were determined by AA and K was determined by flame emission on the same instrument (Greweling 1976). Phosphorus was determined by the ammonium metavanadate-ammonium molybdate procedure (Greweling 1976). Nitrogen was determined by semimicro kjeldahl procedures (83.7, 83.8) to include nitrates (Bremner 1965).

Statistical Analyses

Data were analyzed by the method of least squares to fit general linear models. Orthogonal differences between crested wheatgrass and the forb accessions and between alfalfa and globemallows were assessed by single degree of freedom contrasts. Mean element concentrations within each year of test were correlated with accession forage selection ratios analogous to those proposed by Stuth (1991) and described by Rumbaugh et al. (1993).

Results and Discussion

Mean element concentrations (mg g^{-1}) of alfalfa that are often used in nutrition studies are 17 Ca, 3 P, 20 K, and 2.7 Mg (NRC 1958). Reported concentrations in crested wheatgrass are 4.1 Ca, 2.1 P, and 2.8 Mg. Element concentrations measured in alfalfa grown in southern Idaho and adjacent states averaged 14 Ca, 2.2 P, 22 K, and 2.7 Mg (Clark et al. 1987). Crested wheatgrass from 2 sites in Nebraska contained 2.8 Ca, 1.5 P, 14 K, and 1.0 Mg (Clark et al. 1987). We obtained similar values in our grazing trial. (Table 1).

Narrowleaf globemallow [*S. angustifolia* (Cav.) Don] foliage was reported to contain (mg g^{-1}) 33 Ca, 27 K, 3.6 Mg, and 3.1 P (NRC 1958). These concentrations of Ca and K exceed those of the globemallow species included in our experiment. Munroe globemallow *(S. munroana)* foliage grown in northern Utah contained (mg g^{-1}) 6–19 N, 13–17 Ca, 10–21 K, 2.7–4.3 Mg, and 1.1–2.6 P (B.M. Pendery, personal communication). In that experiment, Ca and Mg concentrations were highest in the fall and lowest in the spring whereas N, P, and K concentrations were highest in spring. In our experiment, levels of N and Mg in *S. munroana* were higher than previously measured (B.M. Pendery, personal communication) but levels of other elements were comparable (Table 1). Nitrogen concentration of *S. coccinea* in northern Colorado peaked at 28 (mg g^{-1}) in May (Simonson et al. 1982). This concentration was lower than in the leaves of the *S. coccinea* accessions we sampled, but higher than the concentrations in the stems of our study plants. When seasonal effects on all species included in our experiment were considered, leaf Ca was highest ($P<0.05$) in fall and leaf N and P highest ($P<0.05$) in spring. Stem N ($P<0.01$), P ($P<0.01$), and K ($P<0.05$) were higher in spring than fall but stem Na was higher in fall than spring ($P<0.01$).

Leaves of the globemallow species differed ($P<0.05$) in concentration of Cu, Mn, Na, P, and Mg. Stem element concentrations of the species differed ($P<0.05$) only for Cu, K, Mg, Na, and Zn. These differences were greater in leaves than in stems (Table 1). The high concentration of Na in the low statured *S. coccinea* did not appear to be the result of soil contamination because Fe values, used as a measure of soil contamination (Mayland and Sneva 1983), did not differ among species ($P>0.05$). Calcium, Mg, P, Cu, and Na concentrations in globemallow leaves and stems generally tended to exceed those in crested wheatgrass, but the concentrations of N, K, Mn, and Zn tended to be greater in crested wheatgrass stems than in globemallows stems. Single degree of freedom contrasts indicated that alfalfa did not differ significantly ($P>0.05$) from globemallows in the concentration of any element other than Fe in either leaf or stem tissues. Crested wheatgrass stems contained significantly more Fe than alfalfa stems and significantly less ($P<0.01$) Ca than the stems of forbs. Globemallows contained more leaf Fe than either crested wheatgrass or alfalfa ($P<0.05$). When compared to the forbs, crested wheatgrass is characterized as having a very high K/Mg ratio and a very low Ca/P ratio.

The dynamics of some macro-elements in some forage species are known to vary primarily as a function of whether the tissues are alive or dead (Greene et al. 1987). Species, absolute age of tissue, and growth patterns also can alter element concentrations. All of the tissues analyzed in our experiments were alive at the time of harvest. The Portneuf soil is more productive than many rangeland soils upon which crested wheatgrass is seeded and, as a result, probably all species did not senesce as early in the season as they would on less fertile range sites. Differences in phenological stage among the species at harvest also were minor (Rumbaugh et al. 1993). Differences among years in which forage was sampled were significant ($P<0.01$) for all element constituents and ratios in both leaves and stems, with the exception of stem Ca (data not shown). For approximately half of the element constituents, seasonal affects were significant ($P<0.05$).

Greene et al. (1987) concluded that seasonal patterns of element concentrations were similar in forages of comparable phenology

Table 1. Element concentrations in leaves and stems of globemallow and alfalfa and in leaves plus stems of crested wheatgrass. Seasonal means are based on all accessions.

Genus Species Season	Microminerals					Macrominerals					Ratios		
	Cu	Fe	Mn	Na	Zn	Ca	Mg	N	P	K	K/(Ca+Mg)	K/Mg	Ca/P
	- - - - - - - - - - - - - $\mu g\ g^{-1}$ - - - - - - - - -					- - - - - - - - - - - - - mg g^{-1} - - - - - - - - -					- - meq - -	- - - ratio - - -	
						Leaves							
S. coccinea	18	1230	61	1050	30	24	5.2	32	3.2	18	0.4	4.2	10
S. grossulariifolia	14	1560	62	160	41	24	5.4	38	3.9	18	0.3	3.5	8
S. munroana	16	1200	58	150	41	27	6.0	37	3.6	18	0.3	3.2	8
S. parvifolia	15	1400	60	240	42	25	5.7	38	3.6	18	0.3	3.3	8
Globemallows	15	1400	60	340	40	25	5.6	37	3.6	18	0.3	3.5	8
Wheatgrass	10	550	99	70	45	6	1.8	35	2.1	23	1.6	13.2	3
Alfalfa	12	610	66	260	27	28	4.9	41	3.0	17	0.3	3.4	12
Species mean	14	1090	68	320	38	22	4.8	37	3.2	19	0.5	5.1	9
LSD (0.05)	3	310	6	330	5	1	0.5	2	0.4	1	0.0	0.5	1
						Stems							
S. coccinea	21	460	31	810	44	16	4.7	23	2.4	18	0.5	4.2	10
S. grossulariifolia	15	390	22	320	33	14	4.5	23	2.3	20	0.5	4.3	8
S. munroana	14	360	20	280	28	13	5.6	21	2.3	22	0.6	3.9	7
S. parvifolia	16	440	23	470	32	14	5.4	22	2.3	22	0.5	4.1	8
Globemallows	16	420	24	470	34	14	5.1	22	2.3	21	0.5	4.1	8
Wheatgrass	10	550	99	70	45	6	1.8	35	2.1	23	1.6	13.2	3
Alfalfa	9	190	17	370	18	9	3.5	23	1.9	20	0.8	5.7	9
Species mean	14	400	35	390	33	12	4.2	24	2.2	21	0.8	5.9	7
LSD (0.05)	4	180	7	240	6	2	0.6	2	0.2	2	0.1	0.6	3
Seasonal mean													
						Leaves							
Fall	13	1680	78	430	37	30	5.7	30	2.7	17	0.3	3.6	12
Spring	16	890	48	210	42	17*	4.8	43*	4.3*	19	0.5	4.7*	4*
						Stems							
Fall	14	430	31	620	31	13	3.8	15	1.2	13	0.4	3.8	12
Spring	16	400	25	240**	36	14	5.9	32**	3.4**	30*	0.8*	6.0*	4
Grand mean	14	750	52	350	36	17	4.5	31	2.7	20	0.6	5.5	8

*,**The difference between the seasonal means for the indicated plant part is statistically significant at $P<0.05$ or $P<0.01$, respectively.

and ontogeny. Herbage P levels of a southern mixed-grass prairie were below the requirements of spring calving cows regardless of the season of the year (Pinchak et al. 1989). Calcium concentration exceeded the livestock requirements throughout the year whereas K and Mg concentrations ranged from adequate during periods of rapid vegetation growth to marginally inadequate during periods of water- (drought) or temperature- (winter) induced dormancy. Plant and animal breeding have been suggested as appropriate procedures to reduce the incidence of grass tetany or hypomagnesemia in cattle (Sleper et al. 1989, Greene et al. 1989). The high levels of foliar Mg in alfalfa and globemallows indicate that grazing management practices that perpetuate these palatable forbs may be as effective as breeding grass for increased foliar Mg or animals for reduced incidence of hypomagnesemia. However, grass tetany usually occurs when temperatures facilitate accelerated grass growth, but are not yet warm enough for appreciable forb growth.

Macroelement requirements for sheep (mg g^{-1} diet dry matter) are Ca (2.0–8.2), P (1.6–3.8), K (5.0–8.0), Mg (1.2–1.8), and Na (0.9–1.8) (NRC 1985). Microelement requirements for sheep ($\mu g\ g^{-1}$ of the dietary dry weight) are Fe (30–50), Mn (20–40), Zn (20–33), and Cu (7–11). The nutritive requirements for medium frame, yearling heifers are approximately the same as those for sheep (NRC 1984). In our study, most of the forage sampled met these nutritive requirements in both fall and spring although crested wheatgrass was deficient in Na (Table 1). Arthun et al. (1992) also concluded that maintaining palatable forbs, such as *S. coccinea*, on rangelands should reduce the need to supply cattle with protein during periods when grasses are dormant.

Globemallows are preferred dietary components of rangelands for several species of ruminants (Howard et al. 1990, Mellado et al. 1991, Rumbaugh et al. 1993). In this study, sheep preferred forage that contained high concentrations of leaf N and high stem Ca/P ratios and avoided stems with high concentrations of Zn (Table 2).

Table 2. Simple correlation of forage selection ratios with element concentrations in the leaves and stems of globemallows.

Elements and element ratios	Correlation coefficients	
	Leaves	Stems
	- - - - - - - - - - - - - - r - - - - - - - - - - - -	
Calcium	–0.05	0.32
Copper	0.02	–0.03
Iron	–0.21	–0.24
Magnesium	0.09	0.27
Manganese	–0.07	–0.18
Nitrogen	0.40**	0.07
Phosphorus	0.23	0.01
Potassium	0.22	–0.33
Sodium	0.09	0.41
Zinc	0.07	–0.67**
Calcium/Magnesium	–0.09	–0.23
Calcium/Phosphorus	–0.11	0.52*
Potassium/Magnesium	–0.12	–0.25

*,** $P<0.05$ and $P<0.01$, respectively.

Some of these preferences might be due to other factors, e.g., the sheep may have preferred young, succulent leaves which were also high in N. In general, a pasture containing crested wheatgrass and 1 or more species of globemallow or alfalfa would meet the dietary element requirements of sheep and most classes of beef cattle provided that forb plant density and animal intake were adequate.

Conclusions

Concentrations of herbage macro- and micro-elements differed among globemallow species. Average concentrations also differed between forbs and crested wheatgrass. The element contents of globemallows and alfalfa were similar. Sodium was more concentrated in stems than in leaves. Nitrogen, P, and K levels were higher in the spring than in the fall whereas Na levels were higher in the fall. Calcium and Mg levels in crested wheatgrass were not adequate for sheep and cattle pasturage without element supplementation. Pastures containing crested wheatgrass and globemallows or alfalfa would be nutritionally adequate for livestock in both spring and fall. Sheep preference for certain accessions, as measured by selection ratios, was positively related to leaf N levels and stem Ca/P ratios. High stem Zn concentration was negatively related to sheep preference.

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